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GCSE Combined Science

Stephanie Anstey
Emma Dougan
Ayd Instone

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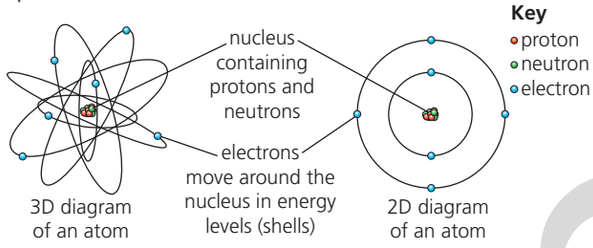
4 Atomic model and bonding of atoms

Overview

Knowledge recap

- A substance containing only *one type of atom* is called an *element*. An atom consists of *protons, neutrons* and *electrons*.
- Protons and neutrons make up the *nucleus* and contain the *mass of the atom*. This is the mass number of an element on the periodic table.
- The *atomic (proton) number* is the *number of protons* found in the atom of an element.



- An *isotope* is a different version of an element. Isotopes have the *same number of protons and electrons* and the *same chemical properties* but *different numbers of neutrons*.
- Electrons *orbit* the nucleus in *different energy levels*. The relative mass of an electron is so small it does not affect the mass of the atom.
- *Relative atomic mass* is the *average mass of all the various isotopes* of that particular element.
- Atoms have an overall charge of 0 as the number of protons (+1 charge) is the same as the number of electrons (–1 charge).
- An *ion* is formed if *electrons are gained or lost*, as the atom becomes *negatively* or *positively charged*.

Practice questions

1 Calculate the number of electrons that are shared in a molecule of oxygen. (1)

UpGrade
Determine the group number(s) of the element(s) that are bonded together. This indicates how many electrons are in the outer shell and therefore how the atoms bond.

2 Draw the electron configuration for Al and for its ion Al^{3+}. (2)

3 Use the information in the periodic table to complete the blanks in the table below. (3)

Atom/ion	Atomic number	Electron configuration
	15	2, 8, 5
K^+		

UpGrade
Use the periodic table to determine which types of elements usually bond together and infer the type of bonding. Metals are on the left-hand side and non-metals on the right.

4 Determine the type of bonding in potassium sulfide and state the chemical formula. (2)

Extended responses

Worked example

1 Over time, the accepted model of the atom has changed considerably. Compare the plum pudding model of the atom and the current model of the atom. (6)

UpGrade
For compare questions, you must explain how the two models are *similar* as well as how they are *different*. Exam reports show that students tend to focus only on the similarities.

Plan your answer to this question in the space below. Start by circling the command word and then highlight or underline any useful information. When writing your plan, consider numbering your points in the order you would write them.

Here is a sample answer with expert commentary:

This is not clear enough as the student has used the pronoun 'it' rather than stating which model they are referring to.

It was a positively charged ball with bits of negative in random areas. The nuclear model has a positively charged nucleus, where the mass of the atom is. This is surrounded by negative electrons occupying different energy levels. The plum pudding model did not have a nucleus but the atomic model does. The plum pudding model was wrong because the electrons were not surrounding the nucleus, but embedded within the sphere.

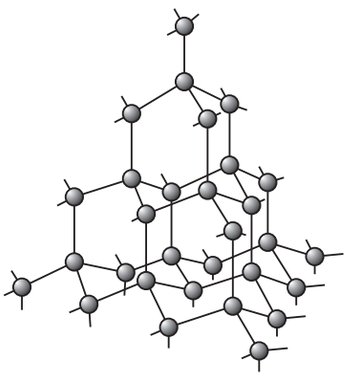
This is a good statement about the correct charges of the nucleus and electrons, but it could be improved by stating which subatomic particles make up the nucleus.

This is a confusing sentence as they have identified why the plum pudding model was incorrect, but have contradicted themselves by implying it contains a nucleus.

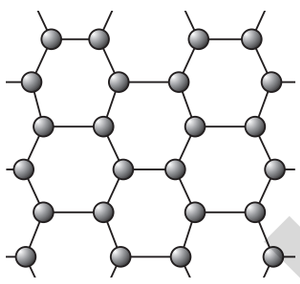
This answer would get 3/6 because the student has shown they understand the basic differences between the two models of the atom but has failed to compare in detail or use the correct terminology to specify the subatomic particles.

Be the examiner

2 Diamond and graphite, shown in figures below, are both macromolecules made from carbon. Compare their bonding and structure, and explain how these relate to their respective properties. (6)



Diamond



Graphite

Insight

The command word is particularly important for extended response questions. Often, students 'describe' rather than 'explain', which prevents them from obtaining higher marks.

Read through the sample answer below and comment on what is good and bad about it.

Graphite and diamond look very different although they are both made from carbon. Diamond is shiny and expensive, whereas graphite is found in pencils. Diamond is a giant covalent structure and each carbon atom is bonded four times. Graphite is bonded covalently but is only bonded three times. Graphite is soft but diamond is hard. Graphite can conduct electricity as it contains delocalised electrons; however, diamond does not conduct electricity.

Use the mark scheme below to help identify how the student did. Use your comments and what you have checked off to give the answer a mark.

Level descriptors	Marks	
Indicative content • Description of diamond as a macromolecule formed from carbon which has covalently bonded four times • Description of graphite as carbon which has covalently bonded three times, forming flat layers • Diamond and graphite both have high melting points due to strong covalent bonds which need to be broken • Graphite conducts electricity as it contains delocalised electrons, but diamond does not • Diamond is very hard as the bonds form a continuous three-dimensional structure • In comparison, graphite is very soft as the layers are held together by weak forces of attraction		☐ ☐ ☐ ☐ ☐ ☐
Level 3: A detailed explanation of both diamond and graphite's bonding and structure is given. Their properties are explained and linked back to how they are bonded. A comparison between the structures must be made. Correct terminology is used throughout.	5–6	☐
Level 2: Explanations are given which clearly state the number of times carbon bonds for diamond and graphite. Student highlights that both structures are bonded covalently. An attempt to compare both structures.	3–4	☐
Level 1: A short description of the number of times carbon bonds for diamond and graphite is given, but there is limited additional information.	1–2	☐

I would give this _____/6 because _____

_____

_____

Practice question

3 Magnesium reacts with fluorine to produce magnesium fluoride, as seen in the equation $Mg(s) + F_2(g) \rightarrow MgF_2(s)$.

Describe the types of bonding in the reactants and explain how the product is formed in terms of electron movement. (6)

Read through the sample student answer below and make notes on how you would improve it.

Magnesium is a metal, so is bonded metallically and fluorine is a non-metal. Magnesium fluoride is formed when a metal and non-metal react. In this type of bonding electrons move from one atom to the other.

Insight

Examiner reports show that students who use pronouns in longer answers instead of the actual names of compounds or molecules lose out on marks because their answers lack clarity. Make sure you are specific.

Write an improved response to this question that would get full marks.

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Practical Chemistry

Practice questions

This question is about the properties of different substances in a chemical reaction. Students often find it difficult to explain how reactants change to form new products, particularly when there are multiple types of chemical bonding involved.

1 When potassium and water react together they produce potassium hydroxide and hydrogen gas as seen in the equation $2K + 2H_2O \rightarrow 2KOH + H_2$.

1–1 Suggest two safety precautions that are needed for the experiment as described. (2)

1–2 Using your knowledge of chemical bonding, state the type of bonding for each reactant and product. (2)

1–3 The potassium reacts to form potassium hydroxide. Explain this reaction both in terms of electron movement and ions formed. (3)

1–4 Draw a dot-and-cross diagram for a molecule of water. (3)

1–5 The experiment was repeated with magnesium instead of potassium. Write out a balanced symbol equation for the reaction. (2)

1–6 Describe and explain the structure and properties of an ionic compound. (3)

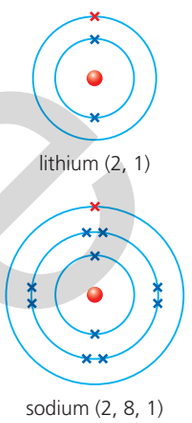
This question assesses your knowledge about group 1 metals and their reactions with water.

Exam questions often ask students to compare the electron configuration of each of the group 1 metals and explain how this affects their reactivity.

2 A scientist was given the first three elements in group 1. They wanted to determine which one would give the most vigorous reaction when placed in a water bath.

2–1 Suggest two control variables needed for the experiment as described. (2)

2–2 Using your knowledge of the group 1 metals and the figure showing electronic configurations of lithium and sodium, explain the patterns in reactivity and determine which chemical would give the most vigorous reaction. (4)



2–3 Draw the electronic configuration for potassium. State how the electronic configuration relates to the location of potassium in the periodic table. (3)

UpGrade
To explain trends in reactivity you should always refer to electron configuration and the number of electron shells. As the number of shells increases, there is more shielding around the nucleus.

2–4 Write out a balanced symbol equation for the reaction of sodium with water. (2)

2–5 Using your knowledge of group 1 metals, explain why the other group 1 metals cannot be used in a school environment. (2)

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Mathematics

The masses of elements on the periodic table are *averages* of the masses of the various *isotopes* which exist and relate to their abundances. The questions in this section will ask you to determine the *relative atomic mass* of different elements, which is a frequent mathematics skill required in Chemistry exams.

Worked examples

1 Isotopes naturally exist in different abundances. Using the table below calculate the relative atomic mass of lithium. Give your answer to two decimal places. (2)

	Lithium-6	Lithium-7
atomic number	3	3
mass number	6	7
percentage	7.50	92.50

Step 1 *Use the equation.*

$$A_r = \frac{(\text{mass no.} \times \% \text{ of isotope 1}) + (\text{mass no.} \times \% \text{ of isotope 2})}{100}$$

Step 2 *Substitute numbers from the table into the equation.*

$$A_r = \frac{(6 \times 7.50) + (7 \times 92.50)}{100}$$

Step 3 *Show each stage in your working out.*

$$A_r = \frac{45 + 647.50}{100} = \frac{692.50}{100} = 6.925$$

A_r of lithium is 6.93 to two decimal places.

Insight

Students often don't give their final answer to the right number of decimal places or significant figures. Remember to check what the question asks for.

2 Boron has two main isotopes, B-10 and B-11. The A_r of boron from the periodic table is 10.8. Calculate the percentage of each isotope. (3)

Step 1 *Use the equation.*

$$A_r = \frac{(\text{mass number} \times a) + (\text{mass number} \times (100 - a))}{100}$$

Step 2 *Substitute numbers into the equation.*

$$10.8 = \frac{(10 \times a) + (11 \times (100 - a))}{100}$$

Step 3 *Show each stage in your working out.*

$1080 = 10a + 1100 - 11a$

$11a - 10a = 1100 - 1080$

$a = 20$

Step 4 *Relate the value back to the question.*

There is 20% of isotope B-10 and 80% of isotope B-11.

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Be the examiner

3 Two main isotopes of copper exist, Cu-63 and Cu-65. There is 69.17% Cu-63. Calculate the relative atomic mass of copper. Give your answer to two decimal places. (2)

Insight

Some students lose marks by rounding numbers *before* the end, which can affect calculations and mean the final answer is incorrect.

Looking at the three answers below, work out which one is correct and why the two others are incorrect.

A

$$A_r = \frac{(65 \times 69.17) + (63 \times 30.83)}{100}$$
$$= 64.3834$$
$$= 64.38 \text{ to two decimal places}$$

B

$$A_r = \frac{(63 \times 65) + (69.17 \times 30.83)}{100}$$
$$= 62.2751$$
$$= 62.28 \text{ to two decimal places}$$

C

$$A_r = \frac{(63 \times 69.17) + (65 \times 30.83)}{100}$$
$$= 63.6166$$
$$= 63.62 \text{ to two decimal places}$$

Answer _____ is correct.

Answer _____ is incorrect because _____

Answer _____ is incorrect because _____

Practice questions

4 Two main isotopes of potassium exist. Determine the number of neutrons for each isotope and then use the values in the table below to calculate the A_r. (3)

	Isotope 1	Isotope 2
atomic number	19	19
mass number	39	41
number of neutrons		
percentage	93.3	6.7

5 Two main isotopes of magnesium exist, Mg-24 and Mg-25. There is 78.6% Mg-24. Calculate the relative atomic mass of magnesium. (2)

6 Two main isotopes of chlorine exist, Cl-35 and Cl-37. The A_r of chlorine from the periodic table is 35.5. Calculate the percentage of each isotope. (3)

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